Boiler and Combustion Safety What You Don't Know CAN Kill You!

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An industrial explosion kills six in Michigan, another kills four in Virginia, and the list goes on. These are only two very tragic, recent national headlines. The November 2000 *National Fire Protection Association (NFPA) Journal* (1), reported that catastrophic fires and explosions cost industry more than $2 billion in 1999. This made 1999 one of the worst years for industrial fire safety in recorded history. These statistics say nothing of the thousands of smaller events that occur and go unrecorded, such as boiler fires, process oven failures, and the burns and injuries from these events. Unfortunately, society and individual companies usually act on these issues only when some very large and tragic event occurs.

This paper hopes to provide a means of encouraging combustion equipment safety action at your facility before it is too late. I hope to raise your awareness about this area of safety that few people know about simply because it is complicated and misunderstood. Combustion equipment safety is critical to the daily operation of all facilities and the safety of every employee. This paper will help you understand how to protect your employees from combustion-related incidents involving fuel-fired equipment (boilers, ovens, pressure vessels) before you end up a headline.

For the non-combustion person, this paper reviews basic gas train safety controls and concepts, and provides an understanding of the most common problems we have found through our inspections of more than 2,000 gas trains, the training of more than 1,000 skilled trades people, and the development of corporate combustion equipment safety programs for some of the world's largest companies.

Most facilities do not have personnel properly trained in combustion equipment maintenance, start-up or shutdown procedures, and/or equipment operations. Most sites also do not follow proper interlock and safety testing guidelines even though they are mandated by law. Boiler safety laws passed by a number of states hoped to help this. Boiler inspections are mandated to be carried out in states and municipalities that have boiler safety laws. These are called jurisdictional inspections. In most states these laws call for inspecting, but not testing, only the pressure vessel part of each boiler system. In 26 states American Society for Mechanical Engineers (ASME) CSD-1 codes have been adopted that mandate actual operational combustion safety systems training. In these states jurisdictional inspectors ask to see evidence of this gas train and safety interlock testing. However, it is beyond their scope to do any of this testing.

"But It Was Just Inspected!"

This is a desperate attempt to suggest that everything humanly possible was done to avoid a catastrophe. People (i.e., owners or operators) think that a jurisdictional boiler inspection is the magic bullet or armor shield, when in fact in many cases it is not. Very few realize what a typical mandated jurisdictional inspection truly is and is not. Many large industrial clients are realizing that these mandated inspections are not enough to protect their most important assets—their employees' lives. Some of these companies now have combustion equipment safety programs that go well beyond minimal legally mandated requirements. These inspections include a detailed check of their combustion systems. This usually includes an analysis for code compliance, installation deficiencies, interlock testing, screening for maintenance practices that can impact safety, and assess technological advances to improve safety.

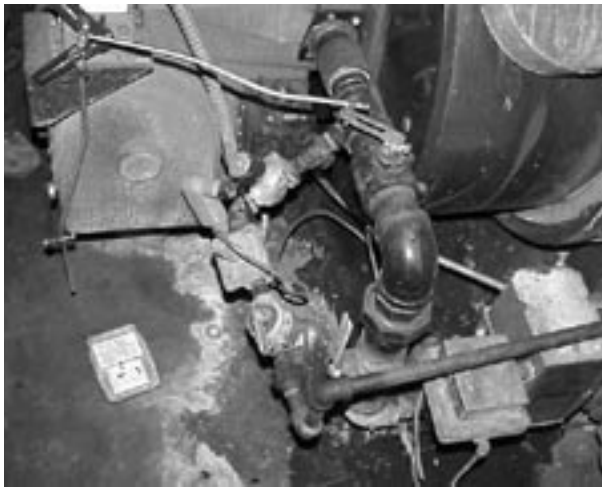


Photo 1. This equipment, in this condition, has been approved to operate "as is" by current jurisdictional inspection practices.

Grandfathering Old Equipment

Jurisdictional inspectors often have their hands tied when it comes to what they can ask someone to do. Often what they are inspecting for is limited by the exact letter of the law. For example, in many cases they can only evaluate equipment for its code compliance when it was installed.

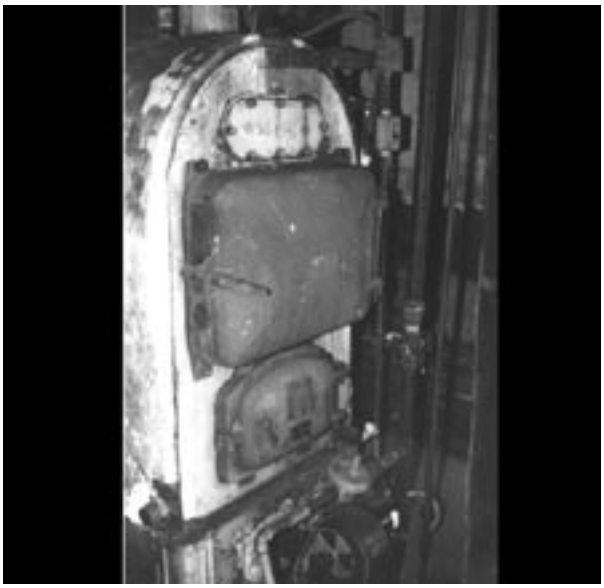


Photo 2. During most inspections archaic equipment like this 60-year-old boiler does not typically get screened for safety upgrades to firing controls.

Typically, there is no screening for how far away from the most recent codes the old "grandfathered" technology is. This kind of inspection sometimes means that you could be "technically" in compliance with archaic and antiquated equipment that is 50 years old or more. This could be equipment that requires many manual steps to operate safely and puts your site at serious daily risk of improper manual start-up or shut-down. You could walk away from this kind of inspection being technically "in compliance," but nowhere near the current codes level of safety or state-of-the-art for the industry.

Consider also that unless you are in a state that adheres to ASME CSD-1 codes, inspections rarely address gas trains and/or fuel system issues. Interlock testing is usually assumed to be a responsibility of the owner, yet interlocks are among the most vital safety components for ensuring that your systems work safely.

When it comes to process ovens, space-heating equipment, furnaces, heat-treaters, and other industrial process users, there are very specific guidelines for protection, but very few people know about them. Often these are custom pieces of equipment with safety controls that are assembled from components. Unlike boiler systems, there are no jurisdictional programs to inspect or test non-boiler, fuel-fired equipment.

What is Interlock Testing? Why Does It Matter?

Burning fuels can be useful as long as it is with a controlled process. Control means that combustion takes place where we want it, when we want it, and at the rate we want it.

Photo 3. Typical gas train with safety interlock components.

The complicated-looking series of valves, wires, and switches that comprise the gas train installed on gas-fired equipment is what attempts to do this.

Photo 4. Most inspections today are only annual at best, and only related to pressure vessels.

Gas trains help us to keep gas out of the combustion chamber when no combustion is taking place through a series of tight, specially designed shut-off valves that are spring-loaded to close. These are the safety shut-off and blocking valves. Larger gas trains require dual valves, and some also have a vent between these valves for added safety. Your specific configuration depends on your insurance and local code requirements.

Gas trains also have a number of components that ensure that safe light-offs take place and that shutdowns occur immediately if anything goes wrong during the operation of the equipment. They do this with a series of pressure switches that detect too high or too low gas pressures to the burner.

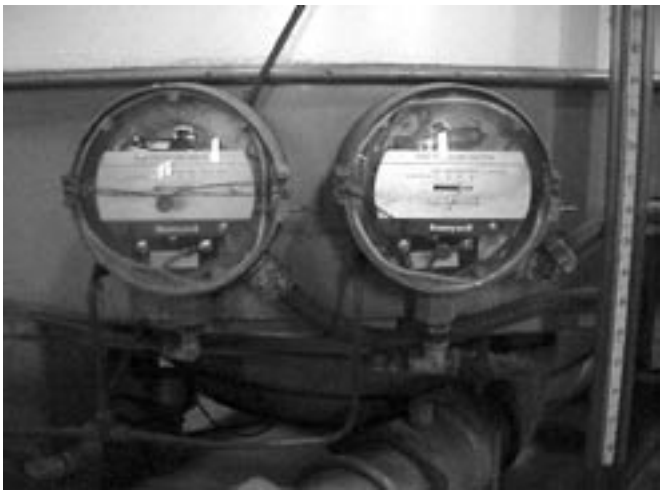


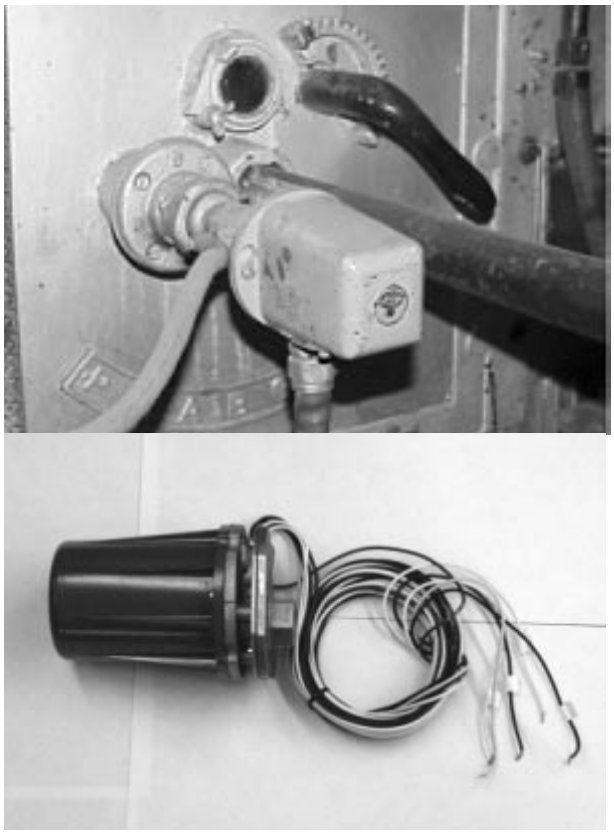
Photo 5. Typical high/low gas pressure switches to verify gas pressures are in the proper range.

Typically, they also have switches to make sure that airflows are correct for purging residual combustibles prior to light-off and that airflow is correct during operation.

Usually, flame-sensing components exist to make sure that flames are present when they are supposed to be present and not present at a wrong time.

Other components for sensing that the fuel valve is at low-fire position prior to light-off may be present, along with furnace pressure switches, high temperature limits, and/or water level cut-outs (depending on the type of equipment).

All of these components are logically linked or interlocked to a burner management system



Photos 6 and 7. Typical flame scanners that monitor flame conditions.

controller (BMS). The BMS is the brain that supervises and sequences all of the light-off efforts and watches as the combustion processes take place. A BMS manages the timing and adequacy of the purge prior to light-off and the time intervals allowed for lighting pilots and main flames.

Photo 8. The burner management system is the brain that monitors/directs safe firing and operations.

By law, all of this equipment should be checked on a regular basis, but with maintenance budgets among the first to be cut, proper checkouts and testing are seldom performed. Codes and manufacturers define what these frequencies are for different types of equipment. Frequencies of required testing vary from daily for some items such as observing flames (assuming you know what to look for), to annually for some block-and-bleed valve tightness testing requirements. It is in this frequency area that we find many problems in industry today.

We typically find that no one is aware of regular testing requirements specified by codes. In most cases we find that sites do some level of testing semi-annually or annually. The level of comprehensiveness varies, depending on who is in charge and that person's knowledge of the equipment or systems.

Where Did the Codes/Industry Protections Originate?

Before you can understand how to protect yourself and your facility, it is important to cover a little background. In the early 1800s, boilers and pressure vessels were at the root of many catastrophes. This created new industries, laws, and infrastructure (from the technical community) to protect the public. This has included the hard work and effort from thousands of dedicated jurisdictional inspectors. They have truly been the backbone of this effort and it has worked very well. Pressure-vessel related incidents have dropped dramatically since that time. These groups have done a wonderful job through the years and have no doubt saved thousands of lives in the process.

Later, additional emphasis was placed on having safe standards for the use of fuels, such as natural gas. Once again, the gas industry, fire protection groups, and insurers came together to identify codes/laws for safe fuel handling and special combustion systems protection. Again, the effort worked. Incidents dropped dramatically.

I want to take you through two equipment situations that we face every day, and describe how and where a plant can get into trouble when it comes to combustion equipment safety, even with all the existing laws, codes, and checks and balances. Let's look at the case of a new facility being built and this same facility after it has been in operation for a number of years.

New Facility

Consider a new facility being built to include gas-fired process equipment and a heating system that includes a boiler.

The project could have been conceived and directed by someone in your corporate staff. It may give you an underlying sense of confidence to think that degreed professionals designed the facility. The plans were then most likely reviewed by a number of people, including the city's building department, the local fire department, an architect, and an insurance company representative. A licensed contractor probably did the equipment installation. You may expect to rest peacefully knowing that probably a dozen skilled professionals have, no doubt, reviewed and blessed everything about the installation.

But all may not be well. Here are some disturbing issues about this scenario.

City Building Departments

City building departments often farm out the review of plans to architects or engineers since they usually do not maintain staff for large projects. Typically, they look for very significant local code related issues. This is most likely not a detailed examination of how your system was selected or installed and it has nothing to do with how it is operated.

They will most likely send an inspector out to see your equipment after it is installed. The inspector is probably a retired tradesman. He will certainly know about residential work because it is probably 75% of what he sees. It is very unlikely that this person would know much about boilers or industrial process equipment.

Corporate Project Engineering Staff

I was a corporate staff engineer for a major oil company. We managed projects. We relied on specialized consultants for giving us advice on equipment selections. In most cases the firms we used relied on vendors to tell them what they needed. This information was translated to drawings and a conceptual specification was generated. Rarely did this level of design include

detailed gas train piping drawings and wiring schematics. In most cases this level was not possible to develop until a specific equipment vendor was selected.

If the design process works correctly, a selected vendor provides detailed drawings for insurance approvals. This step is then followed by a very detailed and thorough commissioning at the site to verify that all was installed and working properly. If these steps happen, then you are likely to be starting off with a very safe site.

Project Architects

Architects receive little or no formal training in building mechanical or combustion systems. It is simply not in their scope. Most likely they will rely on the city's code officials, a hired consulting engineer, and/or a contractor or vendor to provide mechanical or combustion knowledge.

Project Managers

Project managers are (usually) general contractors hired to be schedule and budget people. Once again, it is not typically in their scope of work to spend much time or effort focused on meeting fuel, combustion, or boiler safety codes. They usually assume others address these issues.

Insurance or Mandated Jurisdictional Inspectors

In many cases, jurisdictional inspectors have their hands tied. They are only supposed to review pressure vessel and piping issues including air tanks, water tanks, and boilers. They are not supposed to focus on system issues such as the gas piping at the site, the gas train component settings, control logic, and/or the burner flame pattern.

Local Fire Departments

It would be rare for a fire department to have a boiler or gas equipment expert on its staff. Most fire departments spend the bulk of their time on fire-fighting technologies and issues, such as sprinklers, firewalls, and alarms.

So where does that leave us? It makes for a case where many people may have looked at or have been involved in the new combustion equipment installation, yet no one may have specifically been focused on the combustion safety or fuel system related issues.

OK, So Now It's Installed, But…?

Assume that you ended up with a properly installed and commissioned system. Who is now qualified to operate and maintain the equipment? The staff, consultants, and vendors have now all left your site.

Operations and the human element are the biggest safety issue. The National Board of Pressure Vessel Inspectors (2) statistics for boiler incidents from 1992 through 1998 show that 40% of all deaths, 37% of all injuries, and 31% of all accidents are caused by human error or poor maintenance.

The day after everyone leaves and they have blessed your site, just one person and a well-placed screwdriver can reduce your building to rubble.

Codes offer very little specific direction in this area. The ASME boiler code in Section VII, Subsection C2.110 (3) says "Safe and reliable operation [of boilers] is dependent…upon the skill and attentiveness of the operator and the maintenance personnel. Operating skill implies knowledge of fundamentals, familiarity of equipment, and a suitable background of training and experience. Regularly scheduled auto-manual changeover, manual operation, and emergency drills to prevent loss of these skills are recommended." This kind of training, particularly the mock upset, troubleshooting, or emergency training, may be ignored in most situations we see, even though it is very important. With boilers, there are at least licensures and jurisdictional inspection certifications required. However, this only exists in 26 states. Additionally, many municipalities require no licensures or inspections.

Other codes not related to boilers, such as NFPA 86 1-5.1 to 1-5.5, (4) require that "all operating, maintenance, and appropriate supervisory personnel shall be thoroughly instructed and trained under the direction of a qualified person(s)…and shall receive regularly scheduled retraining and testing." This code also states that operator training "shall include the following, where applicable: combustion of fuel-air mixtures, explosion hazards, sources of ignition including auto-ignition, functions of control and safety

devices, handling of special atmospheres, handling of low-oxygen atmospheres, handling and processing of hazardous materials, confined space entry procedures, and operating instructions."

Many sites assume training happens on-the-job in an informal sense. To these companies, it is information that gets passed on from person to person over coffee or in between baseball scores.

Somehow We're Running Safely, But...

Deterioration and aging happens over time. Dirt accumulates in parts of the burner from the combustion air taken in. Maybe the boiler water treatment has not been stellar, and sludge has accumulated in places. Once in a while, when you stand in a certain place you may smell gas. Maybe there are also age or operationally related situations. Here are some examples.

- During rounds you see what appears to be a slight wisp of steam coming from a small crack near the manhole cover of the boiler mud drum.
- You keep getting low water alarms on a regular basis.
- There appears to be a blackish haze coming from one of your boiler stacks.
- You notice paint peeling from the sidewall of one of the boilers.
- The feedwater line appears to regularly sway where it did not before.
- During a trip up to the roof you smell gas.
- One of the relief valves seems to be weeping.
- During boiler light-offs you hear what sounds like a loud "whomp."

These are all examples of possible operational or maintenance issues that could spell trouble for you and your site. Believe it or not, codes do call for provisions that make for very specific and regular maintenance of certain size boilers and their components. These specific requirements do not cover all boilers. Another problem is that only about half of the states and even fewer municipalities have adopted these as part of their local laws and requirements.

When it comes to gas-fired equipment other than boilers, the codes do not identify specific maintenance frequencies. The guidelines instead

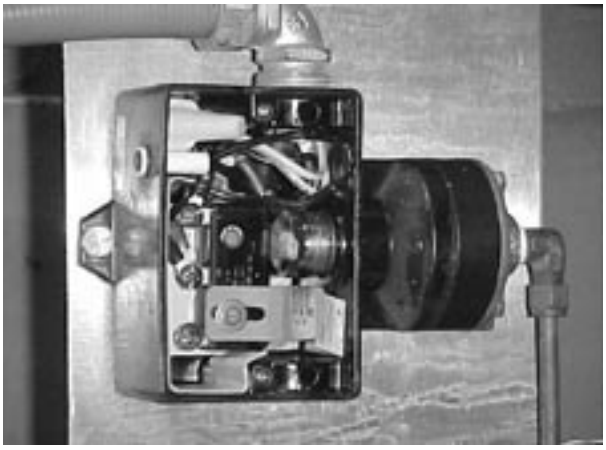


Photo 9. People get creative to defeat safety controls. Here a Popsicle® stick is stuck into an air switch to force it always open.

call for manufacturers' recommendations to be followed. Some manufacturers would have you testing yourself out of business. It is hard to know what is really practical and useful.

This is where the trouble starts. When was the last time you walked into a facility that had been in operation for some time and saw someone with comprehensive interlock testing documentation? We rarely find personnel armed with required component set points, accurate wiring diagrams, and documentation from a manufacturer on testing frequencies and test methods.

If you are in the norm, and you are not doing recommended interlock testing, or do not even know that there is such a thing, you need to change your culture and practices immediately.

Gas Explosions Can Be Avoided: Here's How

Natural gas and combustion equipment safety continues to be a black art among industrial users. Most sites have personnel who are inadequately trained in the safe start-up/shutdown of equipment, daily operations, or its proper testing and maintenance. Our firm's survey of industrial users found that less than 10% actually perform manufacturer or code recommended preventive maintenance including testing of critically important safety interlocks. The combination of these two circumstances can spell disaster and it has in numerous facilities. When assessing your site's circumstances, consider the following.

1. **By far, most of the explosions and fire**

incidents are caused by human error. All of the safeties and interlock equipment in the world will not help if you attempt to short-circuit or jumper-out safety controls. There is no possible substitute for proper training.

2. **Start-up and shutdown are the biggest risks.** You need well-written and clear procedures to make the process very simple and straightforward.
3. **Make sure that you do regular and complete interlock testing.** Jurisdictional inspectors cannot be at your facility every day. Combustion safety and testing needs to be part of your organization's culture.

It is going to take a great deal of effort and change in your company's culture. In the beginning, you'll probably get a lot of the same old, "Gee, we've been doing it this way for years" stories. Our clients have found the first year of having a comprehensive testing and training program to be painful. For these companies, it has taken a lot of effort and faith to start implementing fixes and upgrades on equipment that works, is seemingly fine, but is nowhere near current codes or state-of-the-art in protection.

The bottom line is that implementing comprehensive combustion equipment safety programs has saved lives. We have helped to identify and correct nearly 1,500 failed interlocks and/or critical safety system failures over the past two years. The tides have now turned from aggravation and suspicion among employees to gratitude and thanks.

It is very satisfying to see more and more major companies subscribing to our model checklists. This is proof that there is a valid need and true benefit created by this process.

References

1. National Fire Protection Association, Inc., *National Fire Protection Association Journal*, November 2000.
2. National Board, November 2000, *www.nationalboard.org/Incidents/incidents.html*, November 30, 2000.
3. American Society of Mechanical Engineers, *1998 ASME Boiler & Pressure Vessel Code, An International Code VII, Recommended Guidelines for the Care of Power Boilers Addenda, Subsection C2, C2.110*, 1999.
4. National Fire Protection Association, Inc., "NFPA 86 Standard for Ovens and Furnaces," Chapter 1-5, pp. 86-7, 1999.